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Technical note

Intraoperative determination of lumbar prosthesis endplate lordotic angulation to improve motion

F. Laouissat[a,*], J. Allain[b], J. Delécrin[c]

[a] Centre médico-chirurgical de réadaptation des massues, 92, rue Edmond-Locard, 69322 Lyon cedex 05, France
[b] Service de chirurgie orthopédique et traumatologie, 51, avenue du Mal-de-Lattre-de-Tassigny, 94010 Créteil cedex, France
[c] Service de chirurgie orthopédique et traumatologie, 1, place Alexis-Ricordeau, 4093 Nantes cedex 1, France

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ABSTRACT

The aim of total disc replacement (TDR) is to restore and maintain closer-to-physiology motion. Therefore, the factors that influence postoperative intervertebral motion have to be controlled. Factors such as disc height (DH), postoperative segmental lordosis (SL), implant design and positioning are still recognized to be influent. Otherwise, range of motion (ROM) distribution, between flexion and extension, appear to be influenced by obtaining parallel bearing surfaces, which depends on prosthesis endplate lordotic angulation. To assess in vivo the correlation between an intraoperative parameter (intraoperative segmental lordosis: ISL) and a postoperative parameter (postoperative segmental lordosis: PSL). To determine the advantage of ISL measurement on the improvement of the prosthetic endplate lordotic angulation choice. Radiological comparison between intraoperative and postoperative segmental parameters. Fifty-seven patients who received a TDR at one level, L4–L5 or L5–S1, with different prosthetic endplate lordotic angulations (0°, 5°, and 10°). Twenty-one consecutive patients underwent intraoperative measurement (ISL) on a lateral view, with a spacer at the mid-vertebral bony endplates (Group 1). ISL was correlated using a linear correlation test with PSL. Group 1 postoperative prosthesis endplate lordosis (PEL: angle between the bearing surfaces) were compared to those of 46 patients without intraoperative measurement (Group 2). The mean ISL and PSL angles were 12.2° (7–21°) and 13.9° (8–23°), respectively. We observed a strong linear correlation between ISL and PSL ($r = 0.78$, $P < 0.006$). In Group 1, PEL varied between −1° and 11°, and between −3.7° and 17.8° in Group 2. For 80% of the patients in Group 1, the PEL was less than 5°, versus 33% of the patients in Group 2. Only prostheses with PEL less than 5° had a preserved extension curve in ROM distribution (+3°). Intraoperative measurement of ISL has emerged as a key factor in predicting PSL in TDR. The percentage of parallel bearing surfaces was increased by a prosthesis endplate lordotic angulation choice guided by ISL measurement. This study confirmed the advantage of choosing the adequate lordotic angulation of the prosthesis endplate to restore a physiological motion distribution between flexion and extension.

1. Introduction

Total lumbar disc replacement (TDR) seems to be an alternative to arthrodesis in the treatment of certain cases of chronic discogenic low back pain. The main advantage of TDR is to restore the segmental mobility of the operated intervertebral segment [1].

The efficacy of this intervention on low back pain in terms of functional improvement has been demonstrated over the short and long terms [2–6].

Similarly, several authors have reported maintenance of postoperative sagittal balance and restoration of segmental lordosis (SL) at the level of the implant [7–9]. Other research has emphasized the importance of implantation quality, whose anteroposterior positioning [10–12] may influence segmental mobility amplitude.

In addition, whether or not the implant lordosis matches the SL should have an influence on restoring segmental mobility. The posterior contact or impingement between the two prosthesis endplates, whose contact prevents extension, may be due to excessive postoperative SL, according to Rundell et al. [13]. These authors report the problems predicting postoperative SL during the intraoperative period and the consequent problems selecting the prosthesis endplate lordotic angulation intraoperatively. In theory, the range of motion (ROM) distribution between flexion and

* Corresponding author.
E-mail addresses: flaouissat@gmail.com, legionela@hotmail.fr (F. Laouissat).

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extension should be influenced by whether or not the bearing surfaces are parallel.

However, to the best of our knowledge, no technique guiding the choice of the prosthesis endplate lordotic angulation has been reported. Some authors have reported selecting the prosthesis endplate lordotic angulation based on the "theoretical" lordosis from the relation between the pelvic incidence and lumbar lordosis [14] or the sagittal curve [15] and in relation to the level of the implant. For other authors, the choice of the prosthesis endplate lordotic angulation is based on the "spontaneous" lordosis evaluated in terms of the craniocaudal clearance amplitude of the ancillaries inserted into the disc space after discectomy.

This article presents a surgical technique for TDR investigated on a homogeneous series of patients, with intraoperative measurement, specifically the measurement of intraoperative segmental lordosis (ISL), as well as its relevance in predicting a postoperative parameter (PSL) and in obtaining postoperative parallel bearing surfaces.

The clinical aim of this study was to guide the operator, using a simple surgical technique, toward a relevant choice of prosthesis endplate lordotic angulation to optimise the ROM distribution during TDR.

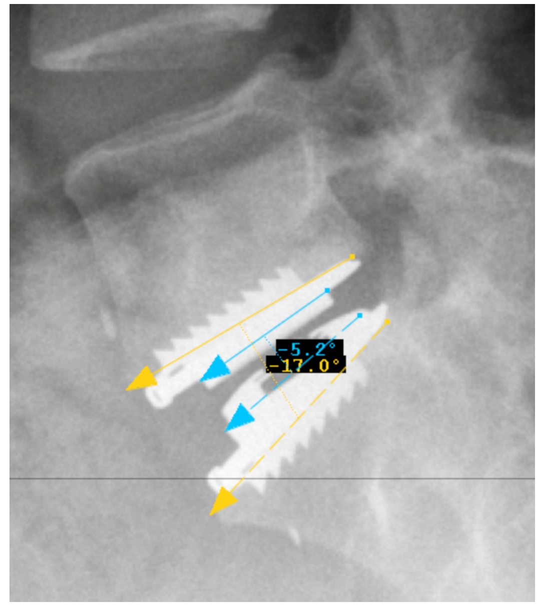

Fig. 1. Postoperative segmental lordosis (PSL, yellow): angle between lower endplate of the overlying vertebra and the upper endplate of the underlying vertebra. Prosthesis endplate lordosis (PEL, blue): angle between the two prosthetic bearing surfaces.

2. Material and methods

2.1. Patient selection

Between January 2004 and January 2011, 67 patients were prospectively included in the study and underwent a mobile-core TDR. All of the patients reported a clinical history of chronic low back pain or radicular pain resistant to properly conducted conservative treatment for at least 6 months before being included in the study. They also presented radiological proof of disc degeneration (standard X-ray, CT scan, MRI, and/or discography).

The patients' mean age was 41.7 years (range, 27–56 years). The series included 34 females and 33 males.

2.2. Radiological measurements

Twenty-one consecutive patients underwent intraoperative measurement of ISL on a lateral X-ray, with a spacer midway between the anterior and posterior vertebral walls (Group 1). ISL was correlated with PSL, measured on lateral X-rays with load at 3 months postoperative, using a linear correlation test.

The angles between the prosthesis bearing surfaces or the prosthesis endplate lordosis (PEL) angle (Fig. 1) of the Group 1 patients was compared to those of the 46 patients with no intraoperative measurement (Group 2).

Segmental mobility was analysed using the Cobb method [16], in terms of ROM distribution between flexion and extension. The overall range of motion was divided into the flexion curve and the extension curve.

2.3. Surgical technique

The 67 consecutive patients were operated through the left or right retroperitoneal approach by the same operator.

The patient was installed in the same way as for an anterior approach to the lumbosacral spine. The patient was installed in the supine position, with the lower limbs in abduction and moderate flexum of both hips. The retroperitoneal approach of the L4–L5 and L5–S1 discs has been described previously [17,18], and its anatomic bases were clearly specified [19,20].

In the case requiring an L5–S1 disc approach, the disc was sealed with a layer containing superior hypogastric plexus fibers. Middle sacral arteries and veins were also placed next to the disc. To maintain the superior hypogastric plexus fibers as intact as possible, the direct approach to the disc is necessarily started on the right edge, whether the initial approach is retroperitoneal left or right. The superior hypogastric plexus fibers contained in the discal and vascular layer have a distribution that predominates toward the left iliac vessels. This layer, which keeps disc exposure in check, is open proximally and distally always on the right side of the disc. The disc is exposed as widely as possible for the TDR implantation (Fig. 2).

When the L4–L5 disc is operated, the vena cava and the left common vena iliaca should always be displaced to the right. This requires releasing their affluences located on their left edge. The distribution of veins at this level varies greatly. The iliolumbar and ascending lumbar veins often need to be ligatured so that the vena cava can be mobilized to expose the right lateral edge of the L4–L5 disc.

Discectomy is subtotal in all cases. The posterior common longitudinal ligament is released or partially sectioned to release the posterior part pinched in the discal space and to re-establish mobility. The vertebral endplates are prepared while preserving the subchondral bone, an important element of the mechanical resistance supporting the prosthetic endplates.

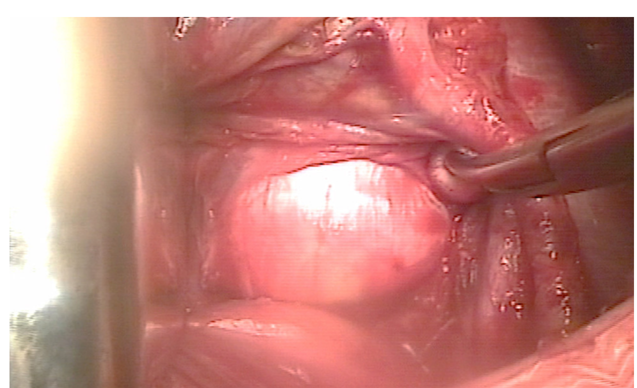

Fig. 2. Intraoperative view: exposure of L5–S1 disc.

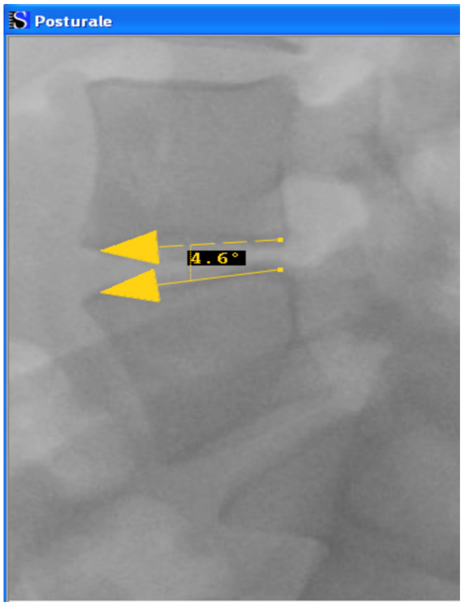

Fig. 3. Segmental lordosis of the intersomatic space before spacer insertion.

After preparation of the intersomatic space, verification is performed using the image intensifier. The source of the image intensifier's angle of incidence is placed as near the patient as possible to limit image distortion as much as possible. On the lateral view, we found it important to check that the image intensifier's angle of incidence was perpendicular to the vertebral endplates (Fig. 3), shown by the absence of splitting the vertebral endplates, the posterior walls, and the pedicles. Then placing the distraction spacers at the mid-vertebral bony endplates, i.e., midway between the anterior and posterior vertebral walls, made it possible to open the intersomatic space and insert the implant guide.

Introducing the spacers influenced two parameters: ISL and disc height (DH).

ISL (Fig. 4) is the angle between the lower surface of the overlying vertebra and the upper surface of the underlying vertebra

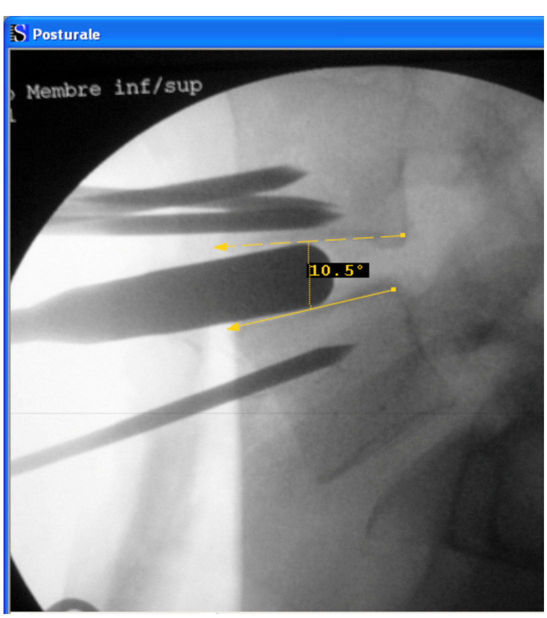

Fig. 4. Measurement of intraoperative segmental lordosis (ILS). The distraction spacer is positioned at the mid-vertebral bony endplates, halfway between the anterior and posterior vertebral walls.

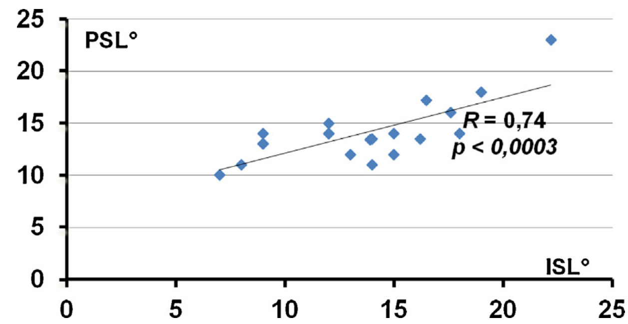

Fig. 5. Linear correlation between ILS and PLS.

during insertion of the spacer at the mid-vertebral bony endplates determined using SpineView® software (Surgiview, Paris, France) after digitizing a screen capture of the image intensifier.

The thickness of the spacer was equal to the implant's thickness, and the DH thus obtained by inserting the spacer should correspond to the height of the final implant.

A spacer that has not been inserted sufficiently (that stops before the mid-vertebral bony endplates) creates insufficient distraction of the intersomatic space. A spacer inserted beyond the mid-vertebral bony endplates causes excessive distraction, with in both cases a different measurement of the ISL.

On this basis, we hypothesized that this disc height, obtained with the spacer at the mid-vertebral bony endplates corresponding to the height of the final implant, could generate ISL (Fig. 4) close to PSL (Fig. 1) providing that the opening of the posterior part of the disc space was sufficient.

Finally, the choice of the prosthesis endplate lordotic angulation (0°, 5°, or 10°) was guided by the intraoperative measurement of ISL, with the lordosis of the prosthetic endplate compensating for the PSL to maintain the bearing surfaces as parallel as possible.

2.4. Postoperative follow-up

Postoperatively, the patients stood up between the first and third day, with adequate analgesics and a soft back brace. Lumbar hyperextension was forbidden.

In the first 6 weeks after the arthroplasty, running, jumping, carrying heavy loads, and major torsion and flexion–extension movements were restricted.

3. Results

None of the patients were lost to follow-up. During the patient follow-up, one patient died and one patient refused the clinical follow-up for personal reasons.

No infectious complications were noted for the patients in the series studied.

No venous or arterial injuries were noted.

Six patients (8.9%) showed problems of the sympathetic system, including two cases of retrograde ejaculation at the beginning of the series. At the last follow-up, problems of the sympathetic system persisted in only two patients.

Two (2.9%) wall hematomas were noted, requiring reintervention.

3.1. Correlation between ISL and PSL

The mean ISL angle and PSL angle were 12.2° ± 3.5°, and 13.9° ± 3.9°, respectively (Fig. 5). A strong linear correlation was noted between ISL and PSL ($r = 0.74$, $P < 0.0003$).

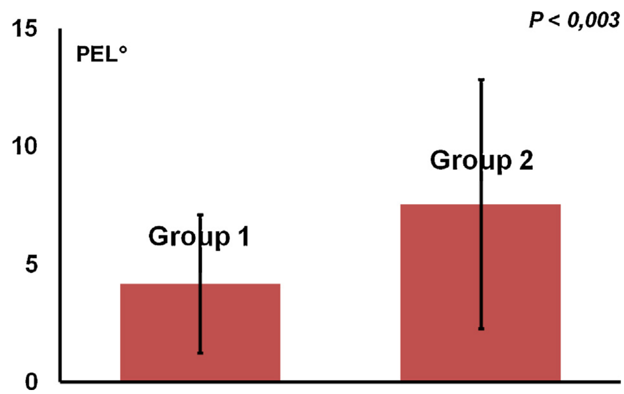

Fig. 6. Mean values of the PEL angle in both groups ($P < 0.003$).

3.2. Parallelism of bearing surfaces

For 80% of the Group 1 patients, the PEL angle was less than 5° (4.2° ± 3.2°) versus only 33% for the PEL angle in the Group 2 patients (Fig. 6) (7.6° ± 4.9°) ($P < 0.003$).

3.3. Influence of PEL on ROM distribution

The increase in PEL values was correlated with the increase in the flexion curve and segmental mobility. However, PEL values greater than 5° led to the extension curve disappearing (Fig. 7a and b).

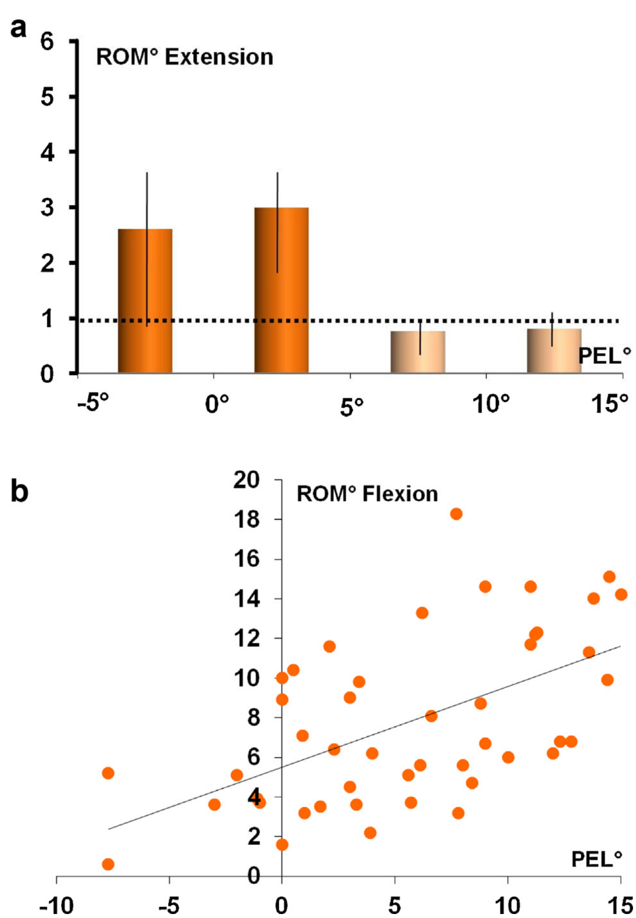

Fig. 7. ROM distribution in relation to PEL angle. a: amplitude of the extension curve; b: amplitude of the flexion curve.

4. Discussion

Our surgical technique aimed to validate the relevance of an intraoperative measurement method, called ISL, to predict the PSL value as well as its advantage in the choice of the prosthesis endplate lordotic angulation. The clinical endpoint of the ISL measurement was to guide the operator in choosing the best prosthesis endplate lordotic angulation so as to optimise the ROM distribution between flexion and extension.

The ISL measurement method seems simple and its application requires maintaining two essential points:

- the distraction spacer should be placed in the middle of the vertebral endplates, mid-distance between the anterior and posterior walls. Spacer placement error could lead to excessive distraction or insufficient distraction of the intersomatic space, with, in both cases, a different ISL measurement;
- it seemed essential to verify that the angle of incidence of the image intensifier is perpendicular to the vertebral plateaux with the source of the angle of incidence located as close as possible to the patient. The operator should ensure that there is no splitting of the vertebral plateaux, posterior wall, and pedicles.

In the present study, we report a strong linear correlation between pSL and ISL, which argues in favour of a decisive role played by ISL measurement and reinforces the relevance of our surgical technique. PSL, which was strongly correlated with ILS, depends most notably on the intraoperative release of the posterior common vertebral ligament, and its disinsertion of the frequently impinged posterior part of the intersomatic space. This release can provide mobility to the intersomatic space. Kasliwal and Deutsch [21] reported no statistically significant correlation between the prosthesis endplate lordotic angulation and PSL. We believe that the intersomatic space will adopt PSL in relation with the quality of the release rather than to the prosthesis endplate lordotic angulation. The function of prosthesis endplate lordotic angulation is not to increase lordosis but rather to obtain parallel prosthetic endplates.

This paper also reports the study of a parameter highlighting the bearing surfaces' parallelism: prosthesis endplate lordosis (PEL), which is defined as the angle between the implant's two bearing surfaces.

PEL appeared to influence the ROM distribution since the increase in the PEL angle was correlated with an increase in the flexion curve of the segmental mobility. On the other hand, a PEL angle greater than 5° leads to the disappearance of the extension curve. This influence of the PEL angle on segmental mobility stems from the kinematics of the mobile-core implant [22]. The more posterior the mean center of rotation, the greater the (residual) segmental lordosis in maximum flexion. Moreover, the extension curve of the segmental mobility disappears if the PEL is greater than 5°, because of an underestimated prosthesis endplate lordotic angulation leading to hyperlordosis in the prosthesis. Inversely, overestimated prosthesis endplate lordotic angulation would cause intraprosthetic kyphosis, which should reduce the flexion curve. This concept, which we have validated in vivo, was suggested in a recent study with in vitro modelling conducted by Rundell et al. [13], who reported that underestimating the implant endplate angle and excessively posterior positioning of the implant increased the risk of impingement or contact of the prosthesis endplates.

Thus, obtaining parallel prosthesis surfaces postoperatively appeared to be essential for balanced ROM distribution and reinforced the importance of the intraoperative choice of prosthesis endplate lordotic angulation. The endplate's lordotic angulation, guided by the method described herein, could indeed compensate the intersomatic space lordosis and restore the distribution of segmental mobility with better balanced ROM distribution between flexion curve and the extension curve.

Other methods to select lordotic angulation have not met with consensus. Some authors report that the choice of prosthesis endplate lordotic angulation is assisted when based on measurement of preoperative SL. However, this choice is limited by the fact that discopathies for which an indication of TDLA is retained are at a stage of intersomatic space impingement or disc collapse. This measurement method is warranted only if the preoperative SL has been measured on old X-rays where the intersomatic space was maintained.

For other authors, the choice of lordotic angulation is based on "spontaneous" lordosis evaluated based on the amplitude of the craniocaudal clearance amplitude of the ancillary material inserted in the discal space after discectomy. This method appears to be simple, but the clearance amplitude can vary depending on the operator skill. In addition, other operators report a choice of prosthesis endplate lordotic angulation based on the theoretical calculation of overall lumbar lordosis. This theoretical calculation of overall lumbar lordosis is based on the pelvic incidence value obtained using a mathematical formula [23], taking into account the correlation between the pelvic incidence and overall lumbar lordosis. The selection of the prosthesis endplate angulation is therefore guided by the difference between the theoretical overall lumbar lordosis value and the preoperative overall lumbar lordosis value. This calculation method is limited when there is no correlation between pelvic incidence and the lordosis of a segment.

The results of the present study have demonstrated the relevance of a method to measure intraoperative SL to predict postoperative SL and have validated its value in choosing the implant endplate. Our simple and safe surgical technique had the clinical endpoint of guiding the operator toward a relevant choice of prosthesis endplate lordotic angulation for a quantitative and qualitative physiological restoration of segmental mobility.

Disclosure of interest

F. Laouissat declares that he has no conflicts of interest concerning this article. J. Allain (*Intérêt* LDR Medical). J. Delécrin (*Intérêt* LDR Medical).

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